[Document Name] SPECIFICATION

[Title of the Invention] METHOD OF CHANGING WIDTH OF SUBSTRATE CONVEYOR AND VARIABLE-WIDTH SUBSTRATE CONVEYOR

[Claims]

[Claim 1] A method of changing a width of a substrate conveyor including:

a pair of guide rails;

a feeding device for feeding a circuit substrate along the guide rails;

a guiding means which guides the circuit substrate being fed by the feeding device, in a longitudinal direction of the pair of guide rails; and

a width changing device for moving at least one of the pair of guide rails toward or away from the other guide rail, to change a distance between the pair of guide rails, the method being characterized by comprising:

a step of operating an image-taking device to take an image of a portion of at least one of the pair of guide rails and controlling the width changing device on the basis of the image taken by the image-taking device.

[Claim 2] The method of changing a width of a substrate conveyor according to claim 1, characterized in that the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a movable-guide-rail position detecting step in which the image-taking device is operated to take an image of a portion of the movable guide rail, and detecting a position of the movable guide rail on the basis of the image taken by the image-taking device; and

a controlling step in which the width changing device is controlled

on the basis of the position of the movable guide rail detected in the movable-guide-rail position detecting step, a position of the stationary guide rail, and a predetermined desired value of the distance between the stationary and movable guide rails, such that an actual value of the distance coincides with the desired value.

[Claim 3] The method of changing a width of a substrate conveyor according to claim 1, characterized in that the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a step of moving the image-taking device to a position determined on the basis of a position of the stationary guide rail; and

a controlling step in which the width changing device is controlled such that the position of the image-taking device coincides with a position of the portion of the movable guide rail.

[Claim 4] The method of changing a width of a substrate conveyor according to claim 1, characterized in that the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a controlling step in which the width changing device is operated to move the movable guide rail, while moving the image-taking device so as to follow a movement of the portion of the movable guide rail, and the width changing device is controlled such that the movable guide rail is moved to a position determined on the basis of a position of the stationary guide rail.

[Claim 5] The method of changing a width of a substrate conveyor according to any one of claims 2 through 4, comprising a

stationary-guide-rail position detecting step in which the image-taking device is operated to take an image of a portion of the stationary guide rail, and a position of the stationary guide rail is detected on the basis of the image of the portion of the stationary guide rail taken by the image-taking device.

[Claim 6] The method of changing a width of a substrate conveyor according to any one of claims 1 through 5, characterized by comprising:

a step of storing in memory means position data representative of a position of a portion of the movable guide rail which was detected during a last operation of the width changing device to change the width of the substrate conveyor; and

an image-taking device positioning step in which the image-taking device is positioned on the basis of the position data representative of the position of the portion stored in the memory means.

[Claim 7] The method of changing a width of a substrate conveyor according to any one of claims 1 through 10, characterized in that the image-taking device is provided by an image-taking device operable to take an image of at least a portion of the circuit substrate, for detecting a position of the circuit substrate which has been fed by the substrate conveyor.

[Claim 8] A variable-width substrate conveyor comprising:

a pair of guide rails;

a feeding device for feeding a circuit substrate along the guide rails;

a guiding means which guides the circuit substrate being fed by the feeding device, in a longitudinal direction of the pair of guide rails;

a width changing device for moving at least one of the pair of guide

rails toward or away from the other guide rail, to change a distance between the pair of guide rails;

an image-taking device operable to take an image of a predetermined portion of at least one of the pair of guide rails;

a moving device operable to move the image-taking device in at least a direction parallel to a direction of movement of the at least one of pair of guide rails toward or away from the other guide rail;

an image processing device operable to process image data which are data of images taken by the image-taking device; and

a control device operable to control the width changing device on the basis of a result of processing of the image data by the image processing device.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates in general to a method of changing a width of a substrate conveyor and a variable-width substrate conveyor the width of which is variable, and particularly to automatic changing of the width of the substrate conveyor.

[0002]

[Prior Art]

A substrate conveyor is provided in various systems and equipment such as an electric-component mounting system for mounting electric components on a printed-circuit board as a kind of a circuit substrate, and conveys the circuit substrate. For instance, the variable-width substrate conveyor includes a stationary guide rail, a

movable guide rail movable toward and away from the stationary guide rail, a pair of endless belts, and a belt-drive device. The pair of endless belts are guided by the stationary and movable guide rails, respectively, and the circuit substrate is supported at its widthwise opposite sides by straight portions of the endless belts. The endless belts are rotated by the belt-drive device, so that the circuit substrate is fed by the endless belts while the circuit substrate is guided at its side edges by the pair of guide rails.

[0003]

The width of the variable-width substrate conveyor is changed depending upon the specific width of the circuit substrate to be fed. The width of the substrate conveyor is changed by changing the distance between the pair of guide rails. Conventionally, the width of the substrate conveyor is automatically changed by a movement of the movable guide rail by a width changing device which uses a servomotor as its drive source, for example. The servomotor is an electric motor whose operating angle can be accurately controlled, so that the movable guide rail can be accurately moved to a position at which the width between the two guide rails corresponds to the width of the circuit substrate.

[0004]

[Objects to be Attained by the Invention, Means for Attaining the Objects and Effects]

However, the servomotor is expensive and inevitably increases the cost of manufacture of the variable-width substrate conveyor.

Further, the use of the servomotor does not necessarily assure a sufficiently high degree of accuracy of varying the width of the conveyor. Where a single servomotor is used to rotate a plurality of

feedscrews arranged in the longitudinal direction of the movable guide rail, for example, the movable guide rail may not be positioned with a sufficiently high degree of accuracy, even if the operating angle of the servomotor itself is accurately controlled, namely, a rotary motion of the servomotor is transmitted to the plurality of feedscrews through a motion transmitting device including chains and sprockets. The accuracy of motion transmission from the servomotor to the feedscrews may be deteriorated due to backlashes and other factors of the motion transmitting device, so that the positioning accuracy of the movable guide rail may be deteriorated.

[0005] It is therefore an object of the present invention to provide a method of changing the width of a substrate conveyor, and a variable-width substrate conveyor, which can solve at least one of the problems of increased cost required for the changing the width and of deteriorated width changing accuracy. The objects indicated above may be achieved according to appropriate ones of the following modes of the present invention, each of which is numbered like the appended claims and depends from the other mode or modes, where appropriate, to facilitate understanding of the invention. It is to be understood that the present invention is not limited to the technical features or any combinations thereof. It is to be further understood that a plurality of features included in any one of the following modes of the invention are not necessarily provided all together, and that the invention may be embodied without some of the features described with respect to the same mode.

[0006] (1) A method of changing a width of a substrate conveyor including:

a pair of guide rails;

a feeding device for feeding a circuit substrate along the guide rails;

a guiding means which guides the circuit substrate being fed by the feeding device, in a longitudinal direction of the pair of guide rails; and

a width changing device for moving at least one of the pair of guide rails toward or away from the other guide rail, to change a distance between the pair of guide rails, the method comprising:

a step of operating an image-taking device to take an image of a portion of at least one of the pair of guide rails and controlling the width changing device on the basis of the image taken by the image-taking device. (Claim 1)

The feeding device of the substrate conveyor described above may include a reciprocating member and a drive device for reciprocating the reciprocating member. The reciprocating member is arranged to move the circuit substrate, in engagement with a portion of the circuit substrate, when the reciprocating member is moved in one of opposite directions in the longitudinal direction of the guide rails. Alternatively, the feeding device may include a pair of endless belts and a drive device for rotating the endless belts. The endless belts are guided by the pair of guide rails and which have straight portions for supporting the circuit substrate at its opposite end portions. The guiding means may consist of a pair of guiding portions of the pair of guide rails, which are formed to guide the circuit substrate at its opposite side edges. Alternatively, the guiding means may consist of positioning portions of the endless belts, which are arranged to engage the opposite side edges of the circuit substrate so as to position the circuit substrate in the direction perpendicular to the longitudinal direction of the guide rails, and which are moved with the endless belts. Alternatively, the guiding means may be a guiding device which is provided separately from the guide rails and the feeding device. The guide rails may

be arranged to directly guide the circuit substrate, or to guide the feeding device. The term “guide rail” is interpreted to not only mean a main body of the guide rail per se, but also include a member which is fixed to the guide rail and which is moved integrally with the guide rail. The term “portion of at least one of the pair of guide rails” indicated above is interpreted to include not only a fiducial mark provided on the guide rail to detect the position of the guide rail, but also a specific portion of the guide rail which is provided for some other purposes, such as a guiding portion provided to guide the corresponding side edge of the circuit substrate.

The pair of guide rails may consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail. Alternatively, the pair of guide rails may consist of two movable guide rails movable toward and away from each other.

The circuit substrate may include: a printed-wiring board on which electric components have been mounted for none of printed wirings formed on an electrically insulating substrate; a printed-wiring board on which electric components have been mounted for some of the printed wirings; a printed-wiring board on which electric components have been mounted and soldered to the printed wirings, i.e., a printed-wiring board where the mounting of the electric components has been completed; a small-size circuit substrate on which a small number of electric components are mounted; and a circuit substrate on which are formed solder bumps for package electric components in which chips are enclosed in protective housings.

According to the method of the present invention, a portion of at least one of the pair of guide rails is imaged by the image-taking device,

so that the position of each of the at least one guide rail whose portion has been imaged can be obtained on the basis of the position of the image-taking device and the position of the taken image of the portion of the guide rail in question in the imaging area of the image-taking device. Accordingly, the image taken by the image-taking device can be used to check if the guide rail has been moved to a desired position at which the desired distance between the guide rails is established to establish the desired width of the substrate conveyor corresponding to the width of the specific circuit substrate, even where the width changing device uses as its drive source an electric motor the operating speed of which can be controlled but the operating amount of which cannot be controlled. The guide rail can be stopped at the desired position on the basis of the image taken by the image-taking device, so that the distance between the guide rails can be changed with high accuracy, without increasing the cost required.

Where the width changing device uses as its drive source a servomotor, the distance between the pair of guide rails can be sufficiently accurately changed, even if a rotation-transmitting device for transmitting a rotary motion of the servomotor to a feedscrew or feedscrews or other driven member or members of the width changing device has backlashes or similar defects. The amount and direction of a positioning error of the guide rail due to the backlashes or similar defects of the rotation-transmitting device can be obtained on the basis of the position of the guide rail which is obtained on the basis of the image taken by the image-taking device. Accordingly, the servomotor can be controlled so as to eliminate the positioning error of the guide rail, so that the guide rail can be accurately located at the desired position corresponding to the desired width of the substrate conveyor.

Since the width of the substrate conveyor can be accurately changed depending upon the width of the circuit substrate according to the method described above, the substrate conveyor can be used, for example, in an electric-component mounting system for mounting electric components on a printed-wiring board, for moving the printed-wiring board to a predetermined component-mounting position. The substrate conveyor permits accurate positioning of the printed-wiring board at the component-mounting position in the system, in an attitude with a reduced error. Accordingly, the printed-wiring board can be positioned such that predetermined spots on the surface of the printed-wiring board at which the respective electric components are to be mounted are located at positions with reduced deviation from respective nominal positions. This reduces a need of compensating the position of a component holder of a component-mounting head of the system when the electric component held by the component holder is mounted on the appropriate spot of the printed-wiring board. Accordingly, the accuracy of mounting of the electric components on the printed-wiring board is improved. Further, the present method eliminates a need of checking if the desired width of the substrate conveyor is established.

(2) The method of changing a width of a substrate conveyor, according to the mode (1), wherein:

the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a movable-guide-rail position detecting step in which the image-taking device is operated to take an image of a portion of the movable guide rail, and detecting a position of the movable guide rail on the basis of

the image taken by the image-taking device; and

a controlling step in which the width changing device is controlled on the basis of the position of the movable guide rail detected in the movable-guide-rail position detecting step, a position of the stationary guide rail, and a predetermined desired value of the distance between the stationary and movable guide rails, such that an actual value of the distance coincides with the desired value. (Claim 2)

The nominal position or detected position of the stationary guide rail may be used as the position of the stationary guide rail.

A desired position of the movable guide rail at which the desired distance between the two guide rails is established is obtained from the position of the stationary guide rail and the desired distance between the guide rails. However, the desired position of the movable guide rail may be obtained from a position data directly designating the desired position itself.

The position of the movable guide rail can be obtained on the basis of the position of the image-taking device and the position of the image of the above-indicated portion of the movable guide rail within the imaging area of the image-taking device. The width of the substrate conveyor can be accurately changed by controlling the width changing device on the basis of the thus obtained position of the movable guide rail, the position of the stationary guide rail and the desired distance between the guide rails, in a manner according to any one of the following modes (3)-(5) of this invention which will be described, for instance.

Alternatively, the actual distance between the movable and stationary guide rails is calculated on the basis of the positions of the two guide rails, and the calculated actual distance is compared with the desired

distance. The desired width of the substrate conveyor may be established by stopping the movement of the movable guide rail when the actual distance becomes equal to the desired distance.

(3) The method of changing a width of a substrate conveyor according to the mode (1), wherein:

the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a step of moving the image-taking device to a position determined on the basis of a position of the stationary guide rail; and

a controlling step in which the width changing device is controlled such that the position of the image-taking device coincides with a position of the portion of the movable guide rail. (Claim 3)

The "position determined on the basis of a position of the stationary guide rail" is a desired position at which the movable guide rail should be located to establish the distance between the two guide rails which corresponds to the width of the circuit substrate and the desired width of the substrate conveyor.

The image-taking device which has reached the desired position waits for a movement of the movable guide rail. The image-taking device can be positioned with high accuracy at the desired position. Accordingly, it is possible to determine that the position of the above-indicated portion of the movable guide rail coincides with the position of the image-taking device, when the image of that portion of the movable guide rail is taken in a predetermined condition, by the image-taking device located at the desired position. The movement of the movable guide rail is stopped when the above-indicated image is taken in the predetermined

condition by the image-taking device, so that the movable guide rail can be accurately located at the desired position, to establish the desired width of the substrate conveyor. The "predetermined condition" may be a condition in which the image of the above-indicated portion of the movable guide rail taken by the image-taking device is aligned with the center of the imaging area (which is a kind of predetermined positions in the image-taking device) of the image-taking device, for instance, or a condition in which there is a deviation between the above-indicated image and the center of the imaging area, which deviation is expected to be zeroed by a movement of the movable guide rail to the desired position after generation of a command to stop the movement while there is the above-indicated deviation.

(4) The method of changing a width of a substrate conveyor according to claim 1, wherein:

the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail, the method comprising:

a controlling step in which the width changing device is operated to move the movable guide rail, while moving the image-taking device so as to follow a movement of the portion of the movable guide rail, and the width changing device is controlled such that the movable guide rail is moved to a position determined on the basis of a position of the stationary guide rail. (Claim 4)

The image-taking device is moved to follow the movable guide rail such that the image of the above-indicated portion of the movable guide rail is held within the imaging area of the image-taking device. Accordingly, the position of the movable guide rail being moved is continuously detected on the basis of the image taken by the image-taking

device, so that the movable guide rail can be stopped at the desired position, on the basis of the position of the image-taking device and the desired position.

As discussed in the part "Embodiments of the Invention", it may be arranged such that the movement of the image-taking device so as to follow the movable guide rail is terminated when the image-taking device has reached a predetermined position close to the desired position, and the image-taking device is moved to the desired position before the movable guide rail reaches the desired position; and when a state where the image of the above-indicated portion of the movable guide rail is taken in the predetermined condition, by the image-taking device at the desired position, the movement of the movable guide rail is stopped, so that the movable guide rail can be located at the desired position with high accuracy. Alternatively, the image-taking device may keep following the movable guide rail until the image-taking device reaches the desired position. The reaching of the movable guide rail at the desired position can be detected by estimation on the basis of the relative position between the image-taking device and the movable guide rail and the position of the image-taking device relative to the desired position. To locate the movable guide rail at the desired position, the movement of the movable guide rail is stopped when it is detected by estimation that the movable guide rail has reached the desired position.

(5) The method of changing a width of a substrate conveyor according to the above mode (1),

wherein the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and away from the stationary guide rail,

and comprising a step of controlling the width changing device so as to minimize an amount of deviation of a position of the image of a portion of the movable guide rail and a predetermined position within an imaging area of the image-taking device, while controlling the image-taking device toward a desired position.

In the above method (5), the image-taking device is moved to the desired position at a deceleration or acceleration value or a speed which is controlled in a predetermined pattern, and the width changing device is controlled such that the movable guide rails follows the movement of the image-taking device.

The image-taking device may be stopped at the desired position before the movable guide rail reaches the desired position, so that the image-taking device detects a movement of the movable guide rail to the desired position. Alternatively, the movement of the movable guide rail is stopped when it is detected by estimation that the movable guide rail has moved to the desired position on the basis of the relative position between the image-taking device and the movable guide rail and the position of the image-taking device relative to the desired position. In the former case, the width changing device is controlled so as to zero the deviation between the position of the image of the above-indicated portion of the movable guide rail and the predetermined position in the imaging area of the image-taking device. In the latter case in which the above-indicated deviation is not zeroed, the width changing device is controlled to move the movable guide rail so as to follow the movement of the image-taking device such that the image of the movable guide rail is kept within the imaging area of the image-taking device.

(6) The method of changing a width of a substrate conveyor

according to any one of the modes (2) through (5), comprising a stationary-guide-rail position detecting step in which the image-taking device is operated to take an image of a portion of the stationary guide rail, and a position of the stationary guide rail is detected on the basis of the image of the portion of the stationary guide rail taken by the image-taking device. (Claim 5)

The position of the stationary guide rail may be detected each time the width changing device is operated to change the width of the substrate conveyor, or only when a predetermined condition is satisfied, for instance, when a predetermined time has passed after the initiation of a working operation on the circuit substrate, or when a working operation is to be performed on the circuit substrate of predetermined kinds.

The stationary guide rail is not necessarily located at its nominal position, due to possible manufacturing and assembling errors. Further, the actual position of the stationary guide rail may change due to thermal expansion, for example. In view of these possibilities, it is desirable to detect the actual position of the stationary guide rail, for establishing the desired width of the substrate conveyor with high accuracy.

(7) The method of changing a width of a substrate conveyor according to any one of the modes (1) through (6), comprising:

a step of storing in memory means position data representative of a position of a portion of the movable guide rail which was detected during a last operation of the width changing device to change the width of the substrate conveyor; and

an image-taking device positioning step in which the image-taking device is positioned on the basis of the position data representative of the position of the portion stored in the memory means. (Claim 6)

The method according to the above mode (7) permits efficient detection of the position of the movable guide rail.

(8) The method of changing a width of a substrate conveyor according to any one of the above modes (1) through (7), comprising a movable-guide-rail searching step of moving the image-taking device over a predetermined range determined by a range of an operating stroke of the movable guide rail, to search the above-indicated portion of the movable guide rail, as the portion of the at least one of the pair of guide rails.

The predetermined search range determined by the range of the operating stroke of the movable guide rail may be the same as or a part of the range of the operating stroke of the movable guide rail, or may be larger than the range of the operating stroke of the movable guide rail, including the entirety of the range of the operating stroke.

For instance, the image-taking device is moved intermittently by a predetermined incremental distance, from one end toward the other end of the range determined by a range of an operating stroke of the movable guide rail. In this case, the image-taking device takes an image of a portion of the movable guide rail at the end of each intermittent motion. The incremental distance is shorter than the dimension of the imaging area (which corresponds to a scope of an image the image-taking device can take at one time) of the image-taking device as measured in the direction of the movement of the movable guide rail. Alternatively, the image-taking device may be continuously moved over the predetermined range.

The movable guide rail is expected to be located at any position within the predetermined range determined by the range of its operating stroke, so that the position of the movable guide rail can be

detected by the searching by the image-taking device over the predetermined range. Thus, the searching by moving the image-taking device permits detection of the position of the movable guide rail, where the position of the movable guide rail is not known at all, or where the position of the above-indicated portion of the movable guide rail is represented by the position data stored in the memory means, as in the method according to the above mode (7), but the actual position of the movable guide rail is different from the position represented by the position data stored in the memory means, because of a manual movement of the movable guide rail by the operator of the width changing device, without updating of the position data according to the manual movement.

(9) The method of changing a width of a substrate conveyor according to any one of the above modes (1) through (8), wherein the above-indicated portion of at least one of the pair of guide rails is a fiducial mark provided on the at least one of the pair of guide rails.

The fiducial mark may take any desired shape, for instance, a circular or elliptical shape, a polygonal shape such as triangle, square or rectangle, or a cross. The fiducial mark may consist of a line or lines.

The fiducial mark may be formed on the guide rail, in any suitable manner, such as by printing directly on the guide rail, or indirectly on a film which is bonded to the guide rail. The fiducial mark may be a raised or recess portion formed on the guide rail. The fiducial mark is required to be formed such that the image of the fiducial mark as taken by the image-taking device has an optical characteristic such as brightness and color, which is different from that of the background of the image, so that the image can be distinguished from the background.

(10) The method of changing a width of a substrate conveyor

according to any one of the above modes (1) through (9), wherein the stationary guide rail and the movable guide rail have a plurality of pairs of fiducial marks which are spaced apart from each other in a longitudinal direction of the guide rails, each of the pairs consisting of two fiducial marks located on the stationary and movable guide rails, respectively, at a same position in the longitudinal direction, and the width changing device is controlled on the basis of the plurality of pairs of fiducial marks.

In the method according to the above mode (10), the distance between the stationary and movable guide rails can be obtained at a plurality of positions corresponding to the positions of the respective pairs of fiducial marks in the longitudinal direction of the guide rails, so that the width of the substrate conveyor can be adjusted with high accuracy in the longitudinal direction.

In the present method wherein the two or more pairs of fiducial marks are provided on the guide rails, even where a single drive source is provided to move the entirety of the movable guide rail to change the distance of the guide rails at one time, the distance is obtained at a plurality of positions so that the desired width of the substrate conveyor can be established by the width changing device with a reduced amount of variation of the actual distance between the guide rails in the longitudinal direction, with respect to the desired distance. In this case, the single drive source is controlled such that an average of the distances between the guide rails obtained at the respective different longitudinal positions coincides with a desired value corresponding to the desired width of the substrate conveyor.

(11) The method of changing a width of a substrate conveyor according to the above mode (10), wherein the width changing device is

capable of changing the distance of the stationary and movable guide rails at a plurality of positions in the longitudinal direction, independently of each other, and the width changing device is controlled such that the distance between the fiducial marks of each of the plurality of pairs coincides with a predetermined desired value.

In the method according to the above mode (11), even where there exists a backlash and the like between drive members and driven members of the width changing device or an error in parallelism between the two guide rails, for instance, the distance between the guide rails can be changed with enhanced accuracy in over the entire length of the substrate conveyor, by obtaining the actual distance between the two guide rails at the different longitudinal positions corresponding to the pairs of fiducial marks, on the basis of the images of the fiducial marks, so that a deviation of the actual distance with respect to the desired value can be obtained at the different longitudinal positions, and moving the movable guide rail so as to eliminate the deviation between the actual and desired distance values at the different longitudinal positions. Where the width changing device is capable of changing the distance between the guide rails at three or more longitudinal positions thereof independently of each other, an undesired flexure of one of the stationary and movable guide rails with respect to the other can be corrected by the present width changing device.

The distance between the two guide rails can be changed at the different longitudinal positions independently of each other, by providing the width changing device with either a plurality of drive sources corresponding to the different longitudinal positions, or alternatively a single drive source. In the latter case, the width changing device may use an electric motor as the drive source to rotate a plurality of feedscrews, for

example, two feedscrews for moving at least one of the guide rails, a clutch may be disposed between one of the feedscrews and the electric motor, so that transmission of a rotary motion of the electric motor between the electric motor and the above indicated one feedscrew is permitted and inhibited with the clutch placed in respective engaged and released positions, and so that the other feedscrew is directly connected to the electric motor. When the width of the substrate conveyor is changed, the clutch is first placed in its engaged position so that the two feedscrews are rotated by the electric motor, to move the movable guide rail relative to a stationary guide rail. The movable guide rail is provided with two fiducial marks corresponding to the respective feedscrews. After the above-indicated movement of the movable guide rail, images of the two fiducial marks provided on the movable guide rail are taken, and the actual distance between the two guide rails is obtained at the two positions corresponding to the two feedscrews, on the basis of the taken images, and compared with the desired value. If the actual distances at the two positions deviate from the desired value, the movable guide rail is first moved with the clutch kept in the engaged state, so as to first zero the deviation detected on the basis of the image of the fiducial mark corresponding to the above-indicated one feedscrew (which is disconnected from the electric motor by the clutch). Then, the clutch is switched to the released position, and the movable guide rail is moved, so as to zero the deviation detected on the basis of the other fiducial mark corresponding to the other feedscrew (which is directly connected to the electric motor).

(12) The method of changing a width of a substrate conveyor according to any one of the above modes (1) through (11), wherein the image-taking device is provided by an image-taking device operable to take

an image of at least a portion of the circuit substrate, for detecting a position of the circuit substrate which has been fed by the substrate conveyor. (Claim 7)

For instance, the image of the circuit substrate taken by the image-taking device is used to detect errors of component-mounting positions on the circuit substrate on which electric components are mounted. When the electric components are mounted on the circuit substrate, the positions of the electric components are compensated for the detected errors, so that the electric components are mounted at the respective component-mounting positions with high accuracy.

In the method according to the above mode (12) wherein the image-taking device provided to take the image of at least a portion of the circuit substrate is utilized to take an image of the predetermined portion of at least one of the guide rails. This image-taking device provided to image the circuit substrate is generally moved with high accuracy, to detect the position of the circuit substrate for assuring a high degree of accuracy of desired working operations to be performed on the circuit substrate, such as operations to mount the electric components (including electronic components) on the circuit substrate. Accordingly, the present method permits accurate and economical adjustment of the width of the substrate conveyor, owing to the utilization of the above-indicated image-taking device to take the image of the predetermined portion of the guide rail or rails.

(13) The method of changing a width of a substrate conveyor according to the above mode (12), wherein the at least a portion of the circuit substrate is a fiducial mark provided on the circuit substrate.

For example, the foregoing description with respect to the above mode (9) applies to the fiducial mark used in the above mode (13).

(14) A variable-width substrate conveyor comprising:

a pair of guide rails;

a feeding device for feeding a circuit substrate along the guide rails;

a guiding means which guides the circuit substrate being fed by the feeding device, in a longitudinal direction of the pair of guide rails;

a width changing device for moving at least one of the pair of guide rails toward or away from the other guide rail, to change a distance between the pair of guide rails;

an image-taking device operable to take an image of a predetermined portion of at least one of the pair of guide rails;

a moving device operable to move the image-taking device in at least a direction parallel to a direction of movement of the at least one of pair of guide rails toward or away from the other guide rail;

an image processing device operable to process image data which are data of images taken by the image-taking device; and

a control device operable to control the width changing device on the basis of a result of processing of the image data by the image processing device. (Claim 8)

The technical features according to any one of the above modes (2)-(13) is applicable to the variable-width substrate conveyor according to the above mode (14).

The substrate conveyor according to the mode (14) has operation and effects as described above with respect to the above mode (1), for instance.

(15) The variable-width substrate conveyor according to the above mode (14), wherein the pair of guide rails consist of a stationary guide rail fixed in position and a movable guide rail which is movable toward and

away from the stationary guide rail, and the image-taking device is operable to take an image of a predetermined portion of the stationary guide rail also.

The substrate conveyor according to the above mode (15) has operation and effects as described above with respect to the above mode (6), for example.

(16) The variable-width conveyor according to the above mode (14) or (15), wherein the predetermined portion of the at least one of the pair of guide rails is a fiducial mark.

For example, the foregoing description with respect to the above mode (9) applies to the fiducial mark used in the above mode (16).

[0007]

[Embodiments of the Invention]

There will be described in detail embodiments of the invention based on drawings.

In Fig. 1, reference sign 10 denotes a machine base or frame of an electric-component mounting system 12. On the base 10, there are mounted an electric-component mounting device 16, a component supply device 18 and a printed-wiring-board supporting and transferring device 20 (hereinafter referred to as "PWB transferring device 20"), which cooperate with each other to mount electric components (including electronic components) on a printed-wiring board. On one side of the PWB transferring deice 20, there is fixedly disposed the component supply device 18. Since the component supply device 18 does not directly relate to the present invention, further description of this device 18 is omitted.

[0008]

The electric-component mounting device 16 will be described first.

As shown in Fig. 2, the electric-component mounting device 16 includes a component mounting head 30, which functions as a component holding head or device. The component mounting head 30 is arranged to hold an electric component 32, and is linearly movable, along mutually perpendicular X-axis and Y-axis, to a desired position above a circuit substrate in the form of a printed-wiring board 24, so that the electric component 32 is mounted on the surface of the printed-wiring board 24. In the present embodiment, the X- and Y-axes are perpendicular to each other in an XY plane of an XY coordinate system. As described later, in the present embodiment, the printed-wiring board 24 is supported in a horizontal attitude, the surface of the printed-wiring board 24 and the XY plane are parallel to the horizontal direction, and the X- and Y-axes are parallel to the horizontal direction.

[0009]

As shown in Fig. 1, two feedscrews 34 are disposed on the base 10, on the opposite sides of the PWB transferring device 20, such that the two feedscrews 34 are spaced apart from each other in the Y-axis direction and extend in the X-axis direction. These feedscrews 34 are held in meshing engagement with respective nuts 38 (only one of which is shown in Fig. 3) fixed to an X-axis slide 36. These feedscrews 34 are rotated in synchronization with each other by respective X-axis drive motors 40 (Fig. 1), so that the X--axis slide 36 is moved in the X-axis direction. In the present embodiment, the feedscrews 34 and nuts 38 are ballscrews and ballnuts which engage each other via steel balls. Other feedscrews and nuts used in the present electric-component mounting system 12 as described below are also ballscrews and ballnuts. On the base 10, there are also disposed two guide members in the form of two guide rails 42 such that

the guide rails 42 are located below the respective feedscrews 34, as shown in Fig. 3. The X-axis slide 36 has a guide block 44 as a guided member at which the slide 36 is slidably supported and guided by the guide rails 42.

[0010]

On the X-axis slide 36, there is disposed a feedscrew 46 so as to extend in the Y-axis direction, as shown in Fig. 3. The feedscrew 46 is held in meshing engagement with a nut 50 fixed to a Y-axis slide 48. The feedscrew 46 is rotated by a Y-axis drive motor 52 shown in Fig. 1, so that the Y-axis slide 48 is moved in the Y-axis direction while being guided by a pair of guide rails 54. The nuts 38, feedscrews 34, X-axis slide 36, X-axis drive motor 40, nut 50, feedscrew 46, Y-axis slide 48 and Y-axis drive motor 52 cooperate with each other to constitute an XY robot 56, which functions as a moving device.

[0011]

As shown in Figs. 1 and 2, the Y-axis slide 48 has a vertically extending side surface 60 on which is vertically movably mounted the component mounting head 30 such that the component mounting head 30 is rotatable about its axis. On the side surface 60, there are also mounted: an elevator device 62 for vertically moving the component mounting head 30; a rotary drive device 64 for rotating the component mounting head 30 about its axis; an image-taking device in the form of a CCD camera 66 (Fig. 1) for taking images of two fiducial marks 65 (Fig. 1) provided on the printed-wiring board 24; and another image-taking device in the form of a CCD camera 68 (Fig. 3) for taking an image of the electric component 32. In the present embodiment, the two fiducial marks 65 are located at respective two corner portions of the rectangle of the printed-wiring board 24, which are opposed to each other diagonally of the rectangle. However,

at least one fiducial mark may be provided on the board 24.

[0012]

In the present embodiment, the CCD camera 66 includes a lens system and an array of CCD elements (charge-coupled elements), which are not shown. The CCD camera 66 is arranged to take a two-dimensional image of an object at one time. The CCD array consists of a multiplicity of minute light-receiving elements which are arranged in a matrix in a plane and generate electric signals depending upon the amounts of light incident thereupon. The matrix of light-receiving elements defines an imaging area. In Fig. 3, the CCD camera 66 is not shown since this CCD camera 66 is superposed on the CCD camera 68, as seen in the plane of Fig. 3. In the present embodiment, the CCD camera 66 has the same configuration as the CCD camera 68, and is positioned with its optical axis extending in the vertical direction such that the CCD camera 66 faces downwards.

[0013]

Similarly to the component mounting head 30, the CCD camera 66 is moved by the XY robot 56 in a direction including at least one of an X-axis component and a Y-axis component, to a desired position in the XY plane parallel to the surface of the printed-wiring board 24. In this embodiment, the XY robot 56 functions as a moving device for moving an image-taking device in the form of the CCD camera 66. On the Y-axis slide 48, there is disposed an illuminating device 69 (see Fig. 1) in opposed relationship with the CCD camera 66. The illuminating device 69 is arranged to illuminate the imaging object and its vicinity.

[0014]

In the present embodiment, the component mounting head 30 includes a component holder in the form of a suction nozzle 70 for holding

the electric component 32 by suction under a negative pressure, and a nozzle holder 72 for removably holding the suction nozzle 70, as shown in Fig. 2. The suction nozzle 70 is held by the nozzle holder 72 by suction. To this end, the nozzle holder 72 is connected to a negative-pressure source 80 and the atmosphere through an air passage 74, a rotary valve 76 and a solenoid-operated directional control valve 78, as shown in Fig 2. With a switching action of the directional control valve 78, the nozzle holder 72 is selectively communicated with the negative-pressure source 80 and the atmosphere, for selectively holding and releasing the suction nozzle 70.

[0015]

On the other hand, the suction nozzle 70 is connected to the negative pressure source 80, a positive-pressure source and the atmosphere through an air passage 84, a rotary valve 86, and solenoid-operated directional control valves 88 and 90. With switching actions of the directional control valves 88, 90, the suction nozzle 70 is selectively communicated with the negative-pressure source 80, the positive-pressure source 92 and the atmosphere, so that the electric component 32 is held by suction by the suction nozzle 70 under a negative pressure, and is released by a positive pressure.

[0016]

There will next be described the PWB transferring device 20.

The PWB transferring device 20 includes a substrate conveyor in the form of printed-wiring-board conveyor 100 (hereinafter referred to as "PWB conveyor 100"), as shown in Fig. 1, and a printed-wiring-board support device (not shown) disposed at a longitudinally middle portion of the PWB conveyor 100, and a printed-wiring-board clamping device which will described. These PWB

conveyor 100, support device and clamping device are arranged in the X-axis direction (in the left and right direction as seen in Fig. 1).

[0017]

The PWB conveyor 100 will be described first.

As shown in Fig. 4, the PWB conveyor 100 includes a pair of guide rails consisting of a stationary guide rail 110 and a movable guide rail 112. The stationary and movable guide rails 110, 112 are disposed in parallel with the X-axis direction and extend in the horizontal direction. The stationary guide rail 110 is fixedly disposed on the base 10, while the movable guide rail 112 is supported movably in the Y-axis direction toward and away from the stationary guide rail 110.

[0018]

On the mutually opposed inner surfaces of the stationary and movable guide rails 110, 112, there are rotatably disposed four rotary members in the form of grooved pulleys 120 located at the longitudinally opposite ends of the guide rails 110, 112. Each of the stationary and guide rails 110, 120 has a guide member in the form of a belt guide 122 fixed thereto at a portion thereof between the two grooved pulleys 120 disposed thereon, as shown in Fig. 6 with respect to the stationary guide rail 110, by way of example. A looped member in the form of an endless belt 124 is wound on the two grooved pulleys 120 and the belt guide 122 of each guide rail 110, 112. When the endless belt 124 is rotated, the rotary movement is guided by the belt guide 124. The endless belt 124 has a projection formed in a widthwise middle portion of its inner surface. The projection of the endless belt 124 engages the annular groove of each grooved pulley 120 such that the projection is slidably movable relative to the pulley 120 in the longitudinal direction of the endless belt 124. Thus, the endless belt 124 is

positioned relative to the grooved pulleys 120 in the width direction of the endless belt 124. The belt guide 124 also has a straight groove (not shown) in its upper surface, and the projection of the endless belt 124 engages this straight groove, for positioning of the endless belt 124 relative to the belt guide 122 in the width direction of the endless belt 124.

[0019]

As shown in Fig. 6, the endless belt 124 supported by the stationary guide rail 110 is further wound on a plurality of tensioners in the form of tension pulleys 128, a plurality of rotary members in the form of grooved pulleys 130, and a driven rotary member in the form of a driven pulley 132. These tension pulleys 128, grooved pulleys 130 and driven pulley 132 are rotatably attached to the stationary guide rail 110. As shown in Figs. 4 and 5, the driven pulley 132 is fixed to a rotation-transmitting shaft in the form of a spline shaft 138 which is rotatably supported at its opposite ends by the stationary guide rail 110 and a support member 136. As shown in Fig. 4, in the present embodiment, the support member 136 is a generally elongate member, and is fixedly disposed on the outer side of the movable guide rail 112, that is, on one side of the movable guide rail 112 which is remote from the stationary guide rail 110. The support member 136 is positioned so as to be parallel with the movable guide rail 112. The spline shaft 138 has a sprocket 140 fixed thereto, and is connected through the sprocket 140 to a drive source in the form of a printed-wiring-board feed drive motor 142. This feed drive motor 142 is an electric motor having an output shaft 144 which has a rotary member in the form of a sprocket 146 fixed thereto. The sprocket 140 is connected to the sprocket 146 through a looped member in the form of a chain 148.

[0020]

As shown in Fig. 6, the endless belt 124 supported by the movable guide rail 112 is wound on a plurality of tensioners in the form of tension pulleys 156, a plurality of grooved pulleys 158 and a driven rotary member in the form of a driven pulley 160. These pulleys 156, 158, 160 are rotatably attached to the movable guide rail 112. It is noted that only one of the tension pulleys 156 and only one of the grooved pulleys 158 are shown in Fig. 5. The driven pulley 160 is attached to the movable guide rail 112 such that the driven pulley 160 is rotatable relative to the guide rail 112 and is held in meshing engagement with the spline shaft 138 such that the driven pulley 160 is axially movable relative to the spline shaft 138 and is incapable of being rotated relative to the spline shaft 138. In this arrangement, a rotary motion of the printed-wiring-board feed drive motor 142 will cause rotary motions of the sprockets 146, 140, and consequently a rotary motion of the spline shaft 138, so that the driven pulleys 132, 160 are rotated to rotate the pair of endless belts 124 in synchronization with each other.

[0021]

The printed-wiring board 24 is placed at its opposite end portions on the straight portions of the endless belts 124, and is fed in a direction parallel to the X-axis direction, in the presence of a friction between the board 24 and the endless belts 124, when the endless belts 124 are rotated. Since the endless belts 124 are supported by the horizontally extending stationary and movable guide rails 110, 112, the printed-wiring board 24 placed on the endless belts 124 is kept in its horizontal attitude while the board 24 is moved along the stationary and movable guide rails 110, 112. In the present embodiment, a belt drive device 162 is constituted

by the printed-wiring-board feed drive motor 142, chain 148, sprockets 146, 140, grooved pulleys 120, 130, 158 and driven pulleys 132, 160. This belt drive device 162 cooperates with the endless belts 124 to constitute a feeding device 164 for feeding the printed-wiring board 24.

[0022]

On the upper surfaces of the stationary and movable guide rails 110, 112, there are fixed respective guide members 170, as shown in Figs. 4-6. These guide members 170 serve as guide portions of the stationary and movable guide rails 110, 112, which function as guide means for guiding the printed-wiring board 24. Each of the guide members 170 is an elongate plate having substantially the same length as the stationary and movable guide rails 110, 112, and has a vertical guiding surface 172. The two guiding surfaces 172 of the two guide members 170, which are opposed to each other in the width direction of the printed-wiring board 24, function to guide the board 24 at the opposite side faces of the board 24, when the board 24 is fed in the longitudinal direction of the guide rails 110, 112. The two guide members 170 has respective presser portions 174 integrally formed so as to extend in their longitudinal direction. These presser portions 174 function to prevent an upward movement of the printed-wiring board 24 during a movement of the board 24, and to clamp the board 24 during the mounting the electric component 32 on the board 24.

[0023]

As shown in Fig. 4, a plurality of guiding members in the form of guide rods 190 are fixedly supported at their end portions by the above-indicated stationary guide rail 110 and support member 136, while a plurality of feedscrews 192 are rotatably supported at their end portions by

the stationary guide rail 110 and support member 136. The guide rods 190 and feedscrews 192 are disposed in parallel with the Y-axis direction. The feedscrews 192 are held in meshing engagement with respective rail nuts 196 fixed to the movable guide rail 112, while the guide rods 190 are held in engagement with respective guide blocks 200 also fixed to the movable guide rail 112. The guide blocks 200 are slidably movable relative to the guide rods 190 in the axial direction of the guide rods 190. Each of the feedscrews 192 has a rotary member in the form of a sprocket 202 fixed at its end portion extending outwardly from the stationary guide rail 110 in its axial direction away from the movable guide rail 112. The sprockets 202 are rotatable relative to the respective feedscrews 192.

[0024]

On the outer surface of the stationary guide rail 110, there are mounted a plurality of tension sprockets 206 such that the tension sprockets 206 are rotatable about their axes parallel to the axis of rotation of the sprocket 202. A looped member in the form of a chain 208 is wound on these sprockets 202, 206. One of the two feedscrews 192 is connected to a drive source in the form of a width changing motor 210 through a speed reducing device 212, so that this feedscrew 192 is directly driven by the width changing motor 210. A rotary motion of the width changing motor 210 is also transmitted to the other feedscrew 192 through the sprocket 202 and the chain 208, so that the two feedscrews 192 are rotated in synchronization with each other, to move the movable guide rail 112 uniformly in its entire length toward and away from the stationary guide rail 110. Thus, a distance between the stationary and movable guide rails 110, 112 can be changed to change the width of the PWB conveyor 100. Although the width changing motor 210 may be an AC motor, the present

embodiment uses a DC motor as the width changing motor 210, so that the operating speed of the motor 210 can be reduced by reducing its energizing time. In the present embodiment, the sprockets 202, chain 208, etc. cooperate to constitute a rotation-transmitting device, which cooperates with the feedscrews 192, rail nuts 196, width changing motor 210, etc. to constitute a width changing device 214.

[0025]

The present embodiment is arranged to permit an operator of the electric-component mounting system 12 to perform an inching operation of the width changing motor 210, for moving the movable guide rail 112. Further, the operator may change the width of the PWB conveyor 100 by manually moving the movable guide rail 112. To this end, a manually operable member in the form of a handle 218 may be connected to one end of one of the feedscrews 192, as indicated by two-dot chain line in Fig. 4. The movable guide rail 112 is moved by manipulating the handle 218.

[0026]

The stationary and movable guide rails 110, 112 are provided with respective fiducial marks 220, 222, as shown in Fig. 4. In the present embodiment, the fiducial marks 220, 222 are formed separately from and attached to the respective stationary and movable guide rails 110, 112. The fiducial marks 220, 222 attached to the guide rails 110, 112 functions as parts of these guide rails 110, 112.

[0027]

The fiducial marks 220, 222 are carried by respective mark carriers 224, 226 each of which is fixed to an end portion of the corresponding guide rail 110, 112 which is on the incoming side of the PWB conveyor 100, as viewed in the direction of movement of the printed-wiring

board 24. The fiducial marks 220, 222 are provided on the upper surfaces of the respective mark carriers 224, 226. In the present embodiment, the fiducial marks 220, 222 are circular in shape, and have an optical characteristic so that the fiducial marks 220, 222 are clearly distinguishable from the other part of the mark carriers 224, 226 not covered by the marks 220, 222. For instance, the fiducial marks 220, 222 have a brightness or color different from that of the background. In the present embodiment, the fiducial marks 220, 222 are white marks formed on the black upper surfaces of the mark carriers 224, 226. However, the fiducial marks 220, 222 may be black marks formed on the white upper surfaces of the mark carriers 224, 226. In the present embodiment, the fiducial marks 220, 222 are printed on the mark carriers 224, 226. However, the fiducial marks 220, 222 may be printed on films, which are bonded to the mark carriers 224, 226. The mark carriers 224, 226 are fixed to the guide rails 110, 112 such that the upper surfaces of the mark carriers 224, 226 have substantially the same level as the upper surface of the printed-wiring board 24 placed on the endless belts 124. The two fiducial marks 220, 222 are located at the same position in the X-axis direction in the present embodiment. However, locating the two fiducial marks 220, 222 at the same position in the X-axis direction is not essential, but the two fiducial marks 220, 222 may be located at different X-axis positions.

[0028]

As shown in Figs. 1 and 3, the X-axis slide 36 carries a prism 240 which is located below the Y-axis slide 48 and between the component supply device 18 and the PWB transferring device 20 in the Y-axis direction. This prism 240 cooperates with the CCD camera 68 to constitute a component imaging system operable to take an image of the electric

component 32, as disclosed in JP-B-2824378, and detailed description thereof is omitted. In this component imaging system, the CCD camera 68 mounted on the Y-axis slide 48 together with the component mounting head 30 is moved integrally with the component mounting head 30. The prism 240 is arranged such that the CCD camera 68 necessarily passes above the prism 240 during a movement of the component mounting head 30 from the component supply device 18 toward the printed-wiring board 24 after the component mounting head 30 has received the electric component 32 from the component supply device 18. Thus, the component imaging system permits the CCD camera 68 to take an image of the electric component 32 without having to stop the movement of the component mounting head 30, and permits the component mounting head 30 to take a shortest path to the printed-wiring board 24. When the electric component 32 is imaged by the CCD camera 68, the electric component 32 is illuminated by a light-emitting body (not shown) accommodated within the suction nozzle 70. With the electric component 32 being illuminated at its upper surface on the side of the light-emitting body, a projection image of the electric component 32 is taken by the CCD camera 68 through the prism 240. The light-emitting body serves as an illuminating device for the electric component 32. A normal image of the electric component 32 may be taken by providing upper and lower front lights disposed on the upper and lower sides of the prism 240, although these front lights are not shown.

[0029]

The present electric-component mounting system 12 includes a control device 250 for controlling the various components of the system, as indicated in Fig. 7. The control device 250 is principally constituted by a computer incorporating a processing unit (PU) 252, a read-only memory

(ROM) 254, a random-access memory (RAM) 256 and a bus 258 interconnecting those devices 252-256. The bus 258 is connected to an image input interface 259 to which the above-indicated CCD cameras 66, 68 are connected. The operations of the CCD cameras 66, 68 are controlled by the control device 250, but this control is not indicated in the block diagram of Fig. 7. The bus 258 is also connected to a servo interface 260 to which are connected various actuators such as the X-axis drive motor 40. The motor 40 and others are electric motors as drive sources and are servomotors in this embodiment, but may be other motors whose operating angles can be accurately controlled. For instance, stepping motors may be used in place of the servomotors.

[0030]

The bus 258 is further connected to a digital input interface 261 to which encoders 266, 268 are connected. The encoders 266, 268 are rotary encoders for detecting the rotating angles of the X-axis and Y-axis drive motors 40, 52. The bus 258 is also connected to a digital output interface 262 to which are connected the printed-wiring-board feed drive motor 142 and the width changing motor 210. Although it is not shown, the motor 40 and others are controlled via a driver circuit, while the CCD camera 66 and others are controlled via a control circuit. These driver and control circuits cooperate with the computer to constitute the control device 250.

[0031]

As indicated in Fig. 8, the RAM 256 has a program memory as well as working memories. The program memory stores control programs for a main control routine (not shown), and various other control programs such as a program for a conveyor-width changing routine

illustrated in the flow chart of Fig. 9.

[0032]

The working memories of the RAM 256 include a MOVABLE-GUIDE-RAIL POSITION memory which stores position data indicative of the position of the movable guide rail 112 in the Y-axis direction in which the movable guide rail 112 is moved toward and away from the stationary guide rail 110, for changing the width of the PWB conveyor 100. When the width changing motor 210 is operated by an inching operation by the operator, the position of the movable guide rail 112 is obtained on the basis of the operating direction of the motor 210, and the total operating angle of the motor 210 which is calculated from the number of inching actions and the operating angle per each inching action. The position data stored in the MOVABLE-GUIDE-RAIL POSITION memory are updated depending upon the position of the movable guide rail 112. Thus, the position data represents the actual position of the movable guide rail 112 in the Y-axis direction. When the width of the PWB conveyor 100 is changed by a manual operation of the handle 182 to rotate the feedscrew 192, the position data stored in the MOVABLE-GUIDE-RAIL POSITION memory are not updated and do not represent the actual position of the movable guide rail 112.

[0033]

When the electric-component mounting system 12 constructed as described above is operated to mount the electric component 32 on the printed-wiring board 24, the PWB conveyor 100 is operated to feed in the printed-wiring board 24 and the printed-wiring board 24 is stopped at a predetermined component-mounting position, by a positioning device (not shown), and supported at its lower surface by a printed-wiring board

support device (not shown) disposed at the component-mounting position. The printed-wiring board support device has a support portion arranged to push up the printed-wiring board 24 at its widthwise opposite end portions (parallel to the X-axis direction), away from the pair of endless belts 124, for forcing the board 24 against the presser portions 174 of the guide members 170, whereby the board 24 is clamped. The support portion and the presser portions 174 cooperate to constitute the printed-wiring-board clamping device.

[0034]

With the board 24 thus positioned and clamped, the CCD camera 66 is moved by the XY robot 56, to take images of the two fiducial marks 65 provided on the board 24. Image data representative of the images are processed by the control device 250, to detect the position of the board 24, for thereby obtaining X-axis and Y-axis errors of a multiplicity of component-mounting positions on the board 24. Then, the component mounting head 30 is moved by the XY robot 56 toward the component supply device 18 to receive the electric component 32 from the component supply device 18, and is then moved toward the printed-wiring board 24. During the movement of the component mounting head 30 toward the board 24, the image of the electric component 32 is taken by the CCD camera 68, and image data representative of the image of the electric component 32 are processed by the control device 250, to detect positioning errors (including center position error and angular positioning error) of the electric component 32 as held by the suction nozzle 70. The electric component 32 is mounted on the board 24 after the position of the axis and the angular position of the suction nozzle 70 are compensated for the positioning errors of the electric component 32, and for the already obtained X-axis and Y-axis

errors of the component-mounting positions on the board 24.

[0035]

The distance between the stationary and movable guide rails 110, 112, that is, the width of the PWB conveyor 100 is changed depending upon a specific kind of the printed-wiring board 24, more precisely, depending upon a specific width of the board 24 as measured in the Y-axis direction (which is perpendicular to the X-axis direction in which the board 24 is fed). An operation to change the width of the PWB conveyor 100 will be briefly described. Initially, the images of the fiducial marks 220, 222 provided on the stationary and movable guider ails 110, 112 are taken by the CCD camera 66, and image data representative of the images are processed by the control device 250, to detect the Y-axis positions of the stationary and movable guide rails 110, 112. The CCD camera 66 can be moved by the XY robot 56 to and stopped at the desired positions with high accuracy, since the XY robot 56 are moved by the X-axis and Y-axis drive motors 40, 52, which are servomotors. Further, the position of the CCD camera 66 can be accurately detected on the basis of the output signals of the encoders 266, 268. Accordingly, the positions of the stationary and movable guide rails 110, 112 can be accurately detected on the basis of the position of the CCD camera 66 and the positions of the images of the fiducial marks 220, 222 within the imaging area of the CCD camera 66.

[0036]

After obtaining the positions of the guide rails 110, 112, a desired position to which the movable guide rail 112 is moved to change the width of the PWB conveyor 100 is obtained on the basis of the detected position of the stationary guide rail 110 and a desired distance of the guide rails 110, 112. The width changing device 214 is operated to move the

movable guide rail 112 to the obtained desired position. At this time, the CCD camera 66 is moved so as to follow the movement of the movable guide rail 112.

[0037]

In the present embodiment, the position of the CCD camera 66 is represented by the position of its optical axis, and the position of the movable guider rail 112 is represented by the position of the fiducial mark 222. When the image of the fiducial mark 222 is taken by the CCD camera 66, the position of the optical axis of the CCD camera 66 is aligned with the Y-axis position of the movable guide rail 112, where the image of the fiducial mark 222 is centered in the imaging area of the CCD camera 66. In this case, the CCD camera 66 is moved to follow the movement of the movable guide rail 112, such that the image of the fiducial mark 222 is kept located in a central portion of the imaging area.

[0038]

When the movable guide rail 112 has been moved to a position close to the desired position, the movement of the guide rail 112 is slowed down, so that the speed of movement of the CCD camera 66 is made higher than that of the guide rail 112. As a result, the CCD camera 66 reaches and is stopped at the desired position before the movable guide rail 112. The CCD camera 66 stopped at this position initiates an imaging operation to take the image of the fiducial mark 222. When the image of the fiducial mark 222 taken by the CCD camera 66 is aligned with the center of the imaging area, it indicates that the movable guide rail 112 has reached the desired position. Accordingly, the movement of the guide rail 112 is terminated. The operating speed of the width changing motor 210 used as the drive source of the width changing device 214 to move the

movable guide rail 112 can be controlled, but the operating amount of this motor 210 cannot be controlled. However, the movable guide rail 112 can be accurately located at the desired position by taking an image of the fiducial mark 222 by the CCD camera 66 to obtain the position of the movable guide rail 112.

[0039]

There will be described the conveyor-width changing routine, by reference to the flow chart of Fig.9.

This routine is initiated with step S1 (which will be referred to as S1, the same applies to other steps, too) to determine whether a flag F1 is placed in an ON state. The flag F1 is provided in the RAM 256, although this is not shown in drawings. The flag F1 placed in the ON state indicates that the positions of the stationary and movable guide rails 110, 112 have been detected, and the movement of the movable guide rail 112 to change the width of the PWB conveyor 100 has been initiated.

[0040]

Since the flag F1 is reset to an OFF state upon initialization in the main control routine, a negative decision (NO) is initially obtained in S1, so that the control flow goes to S2 in which the position of the stationary guide rail 110 is detected on the basis of the center position of the image of the fiducial mark 220 taken by the CCD camera 66. The position of the fiducial mark 220 can be detected on the basis of the position of the image of the fiducial mark 220 in the imaging area and the position of the CCD camera 66, and the position of the stationary guide rail 110 can be determined by the position of the fiducial mark 220.

[0041]

To take the image of the fiducial mark 220, the CCD camera

66 is moved to a known nominal position of the stationary guide rail 110. The image data of the fiducial mark 220 taken by the CCD camera 66 are processed to obtain the position of the stationary guide rail 110. The processing of the image data is effected by a pattern matching technique as disclosed in JP-A-8-180191. The stationary guide rail 110, which is fixed in position, is theoretically located at its nominal position, but the actual position may deviate from the nominal position due to errors in the manufacture of the electric-component mounting system 12. The position of the stationary guide rail 110 is obtained with respect to the X-axis and Y-axis directions. A deviation of the actual position of the stationary guide rail 110 from the nominal position in the longitudinal or X-axis direction has substantially no influence on the width of the PWB conveyor 100 in the Y-axis direction. Since only the position of the stationary guide rail 110 in the width or Y-axis direction is required for changing the width of the PWB conveyor 100, only the Y-axis position of the stationary guide rail 110 may be obtained. However, both of the X-axis and Y-axis positions of the stationary guide rails 110 may be obtained. S2 in which the position of the stationary guide rail 110 is detected, is a stationary-guide-rail position detecting step.

[0042]

Then, the control flow goes to S3 to detect the position of the movable guide rail 112 of the PWB conveyor on the basis of the center position of the image of the fiducial mark 222 taken by the CCD camera 66. Both of the X-axis and Y-axis positions of the movable guide rail 112 or only the Y-axis position of this guide rail 112 may be detected. The position of the movable guide rail 112 is represented by the position data which was stored in the MOVABLE-GUIDE-RAIL POSITION memory, in the last operation to establish the width of the PWB conveyor 100. To take the

image of the fiducial mark 222, the CCD camera 66 is moved to the Y-axis position represented by the stored position data. When the electric-component mounting system 12 is initially turned on, position data representative of the width of the PWB conveyor 100 for the first printed-wiring board 24 on which the electric component 32 may is mounted is stored in the MOVABLE-GUIDE-RAIL POSITION memory of the RAM256, for instance. Alternatively, position data representative of a predetermined initial position of the movable guide rail 112 may be stored in the MOVABLE-GUIDE-RAIL POSITION memory. If the movable guide rail 112 is not moved by the operator using the handle 218 after the last operation to establish the width of the PWB conveyor 100, the movable guide rail 112 is located at the position represented by the position data stored in the MOVABLE-GUIDE-RAIL POSITION memory of the RAM 256. In this case, the CCD camera 66 can be moved on the basis of the stored position data, to take the image of the fiducial mark 222 on which it is possible to check if the actual position of the movable guide rail 112 coincides with the position represented by the stored position data.

[0043]

If the movable guide 112 is moved by the operator with the operation of the handle 218 after the last operation to establish the width of the PWB conveyor 100, the actual position of the movable guide rail 112 is different from the position represented by the stored position data. If the difference between the actual position and the position represented by the stored position data is so small as to permit the CCD camera 66 to take the image of the fiducial mark 222 within the imaging area, the image is taken by the CCD camera 66 without a movement of the CCD camera 66. If the difference is too large to permit the CCD camera 66 to take the image of the

fiducial mark 222 within the imaging area, the image is not taken at the present position of the CCD camera 66, and accordingly the position of the movable guide rail 112 can not be obtained.

[0044]

In this case, the CCD camera 66 is moved in the Y-axis direction over a predetermined search range to detect the fiducial mark 222. In this embodiment, this predetermined search range includes, and is slightly broader than, a predetermined range of the operating stroke of the movable guide rail 112. The movable guide rail 112 is moved only in the Y-axis direction and the predetermined range of the operating stroke of the movable guide rail 112 and the search range respectively extend in the Y-axis direction.

[0045]

For instance, the CCD camera 66 is initially moved to one end of the predetermined search range, and is then intermittently moved toward the other end, by a predetermined incremental distance for each of the intermittent movements. The CCD camera 66 is operated to try to take the image of the fiducial mark 222 each time the CCD camera 66 has been intermittently moved. The distance of the intermittent movements is slightly shorter than the Y-axis dimension of the imaging area of the CCD camera 66. The image of the fiducial mark 222 can be eventually taken by the CCD camera 66, and the position of the movable guide rail 112 is detected on the basis of the position of the CCD camera 66 and the position of the image of the fiducial mark 222 within the imaging area. The operation to move the CCD camera 66 on the basis of the position data stored in the MOVABLE-GUIDE-RAIL POSITION memory is an image-taking device positioning step, and the operation to detect the

position of the movable guide rail 112 is a movable-guide-rail position detecting step, while the operation to search the fiducial mark 222 is a movable-guide-rail searching step.

[0046]

After the position of the movable guide rail 112 is detected, the control flow goes to S4 in which the width changing motor 210 is started to initiate a movement of the movable guide rail 112 toward the desired position, and the flag F1 is turned ON. The movable guide rail 112 is moved at a predetermined speed. The desired position of the movable guide rail 112 represents a position of the movable guide rail 112 in the Y-axis direction (or width direction of the PWB conveyor 100), and is determined by the position of the stationary guide rail 110 and the desired distance between the guide rails. At the desired Y-axis position, the distance between the guiding surfaces 172 of the stationary and movable guide rails 110, 112 is such that the movement of the printed-wiring board 24 is guided such that the feeding of the printed-wiring board 24 is permitted but the movement of the printed-wiring board 24 in the direction intersecting the feeding direction in the plane parallel to the surface of the printed-wiring board 24 is inhibited. In the present embodiment, the desired distance of guide rails is defined by the distance between the fiducial marks 220, 222 on the stationary and movable guide rails 110, 112, and is stored in a DESIRED RAIL DISTANCE memory of the RAM 256 with being associated with the respective kinds of the board 24. An appropriate one of the distance values is read depending upon the specific kind of the board 24 in question.

[0047]

Then, S5 is implemented to have the CCD camera 66

perform its image taking operations and to process the image data obtained by the CCD camera 66. S5 is implemented each time the width changing routine of Fig. 9 is executed. The image taking operations and the image data processing operation is actually implemented with a predetermined cycle time, so that the image of the fiducial mark 222 is captured and processed.

[0048]

After the image taking operations, S6 is implemented to determine whether a flag F2 is placed in an ON state. The flag F2 placed in the ON state indicates that the CCD camera 66 has been moved to the desired position. Since the flag F2 is reset to an OFF state upon initialization in the main control routine, a negative decision (NO) is initially obtained in S6, and the control flow goes to S7 to determine whether the CCD camera 66 has been moved to a position close to the desired position. This determination is effected by determining whether a distance between the Y-axis position of the CCD camera 66 and the desired Y-axis position in the Y-axis direction has become equal to or shorter than a predetermined value. The X-axis and Y-axis positions of the CCD camera 66 can be detected by the output signals of the encoders 266, 268. A negative decision (NO) is initially obtained in S7, and the control flow goes to S8 to effect a control of the movement of the CCD camera 66 so as to follow the movement of the movable guide rail 112.

[0049]

In S8, the movement of the CCD camera 66 is controlled so as to follow the movement of the movable guide, such that the center position of the image of the fiducial mark 222 is kept in alignment with the center of the imaging area of the CCD camera 66. This alignment of the

imaging area of the CCD camera 66 and the image taken by the CCD camera 66 indicates that the CCD camera 66 is moved without delay with respect to the movable guide rail 112. In view of this fact, a deviation of the center position of the image of the fiducial mark 222 with respect to the center of the imaging area of the CCD camera 66 is obtained, and the CCD camera 66 is moved by the XY robot 56 so as to zero the deviation. Normally, the CCD camera 66 is moved at substantially the same speed as the movable guide rail 112, but with a slight delay of the movement of the CCD camera 66 with respect to the movement of the movable guide rail 112. Before the movement of the movable guide rail 112 is initiated, the CCD camera 66 is located at the detected position of the movable guide rail 112.

[0050]

When S1 is implemented after the Flag F1 is placed in the ON state, an affirmative decision (YES) is obtained, and the control flow goes to steps S5-S8 while skipping steps S2-S4. Steps S1 and S5-S8 are repeatedly implemented until the CCD camera 66 has been moved close to the desired position. When an affirmative decision (YES) is obtained in S7, the control flow goes to S9 to determine whether a flag F3 is placed in an ON state. The flag F3 placed in the ON state indicates that the CCD camera 66 has been moved close to the desired position. Since the flag F3 is also reset to an OFF state upon initialization of the main control routine, a negative decision (NO) is obtained in S9, and the control flow goes to S10 in which the CCD camera 66 is further moved to the desired position. S10 is followed by S11 to decelerate the movable guide rail 112 and turn ON the flag F3. Accordingly, the movable guide rail 112 is moved at a lower speed toward the desired position until the movable guide rail 112 comes close to the desired position. On the other hand, the CCD camera 66 is moved at a

speed higher than that of the movable guide rail 112, so that the CCD camera 66 reaches the desired position before the movable guide rail 112.

[0051]

The control flow then goes to S12 to determine whether the CCD camera 66 has reached the desired position. Initially, a negative decision (NO) is obtained in S12, and one cycle of execution of the conveyor width changing routine of Fig. 9 is terminated. Since the CCD camera 66 is moved by the XY robot 56 moved by the servomotors 40, 52, the position and speed of movement of the CCD camera 66 can be controlled. Further, the CCD camera 66 is also decelerated after it has been moved close to the desired position, so that the CCD camera 66 reaches the desired position at a sufficiently low speed. Steps S1, S5-S7, S9 and S12 are repeatedly implemented until the CCD camera 66 has reached the desired position.

[0052]

When the CCD camera 66 has reached the desired position, an affirmative decision (YES) is obtained in S12, and the control flow goes to S13 to stop the movement of the CCD camera 66, and turn ON the flag F2. Step S13 is followed by S14 to determine whether the movable guide rail 112 has almost reached the desired position, that is, has been moved to a position a predetermined short distance apart from the desired Y-axis position in the direction away from the stationary guide rail 110 toward the movable guide rail 112. The predetermined distance is determined so that the movable guide rail 112 is stopped at the desired position by commanding the width changing motor 210 to be turned off at the position close to the desired position. Since the movable guide rail 112 has been decelerated when it has reached the position close to the desired position, the movable guide rail 112 can be stopped exactly at the desired position by turning off

the width changing motor 210 at the position close to the desired position, if the above-indicated distance is suitably determined. As discussed above, the alignment of the position of the image of the fiducial mark 222 with the center of the imaging area of the CCD camera 66 in the direction of the movement of the movable guide rail 112, that is, the Y-axis direction, indicates that the movable guide rail 112 is located at the desired position. In view of the movement of the movable guide rail 112 by the above-indicated distance even after the width changing motor 210 is turned off, S14 is formulated to determine whether the position of the image of the fiducial mark 222 has reached a position which is the above-indicated distance apart from the center of the imaging area of the CCD camera 66 in the Y-axis direction away from the stationary guide rail 110.

[0053]

When S14 is implemented for the first time, a negative decision (NO) is obtained in S14, and one cycle of execution of the present routine is terminated. Steps S1, S5, S6 and S14 are repeatedly implemented until the movable guide rail 112 reaches the position close to the desired position. When an affirmative decision (YES) is obtained in S14, the control flow goes to S15 issue a command to stop the movement of the movable guide rail 112, and to store, in the MOVABLE-GUIDE-RAIL POSITION memory of the RAM 256, the position data representative of the position of the movable guide rail 112, that is, the desired position. Step S15 is further arranged to reset the flags F1-F3 to the OFF state, and effect other processing operations to terminate the execution of the present conveyor width changing routine of Fig. 9. This routine is not executed until the width of the PWB conveyor 100 is changed again. The operation to control the width changing device 214 for moving the CCD camera 66 to

the desired position, following the movement of the movable guide rail 112, is a controlling step of controlling the width changing device 214 to establish the desired width of the PWB conveyor 100. This step includes a step of moving the CCD camera 66 so as to follow the movement of the movable guide rail 112, and a step of decelerating the movable guide rail 112.

[0054]

Although the operating amount of the width changing motor 210 used to move the movable guide rail 112 cannot be controlled, the position of the movable guide rail 112 can be controlled on the basis of the image of the fiducial mark 222 taken by the CCD camera 66 which is moved so as to follow the movement of the movable guide rail 112 and which is provided to take the images of the fiducial marks 65 on the printed-wiring board 24. Thus, it may be considered that the movable guide rail 112 is moved by an electric motor controllable with respect to its amount of operation. Accordingly, the width of the PWB conveyor 100 can be changed with high accuracy, without an increase of the cost of manufacture of the variable-width PWB conveyor 100.

[0055]

It will be understood from the foregoing description of the first embodiment that a portion of the control device 250 assigned to process image data obtained by the CCD camera 66 constitutes an image processing device, while a portion of the control device 250 assigned to implement steps S11, S14 and S15 constitutes a control device operable to control the width changing device 214. It will also be understood that a portion of the control device assigned to implement S8 constitutes a tracing control portion, while a portion of the control device 250 assigned to implement S11 constitutes a deceleration control portion.

[0056]

In the first embodiment described above, when the guide rail 112 is moved to the desired position, the CCD camera 66 is moved so as to follow the movement of the movable guide rail 112. However, the CCD camera 66 may be moved such that the CCD camera 66 reaches the desired position before the movable guide rail 112. The CCD camera 66 located at the desired position waits for the subsequent movement of the movable guide rail 112 toward the desired position, to stop the movable guide rail 112 at the desired position. This modified arrangement will be described as a second embodiment of this invention, by reference to the flow chart of Fig. 10.

[0057]

According to the second embodiment, the width of the PWB conveyor 100 is implemented based on the conveyor width changing routine of the flow chart of Fig. 10. The conveyor width changing routine of Fig. 10 is initiated with S31 to determine whether a flag F11 is placed in an ON state. The flag F11 placed in the ON state indicates that the CCD camera 66 has reached the desired position. Since the flag F11 is reset to an OFF state upon initialization or others, a negative decision (NO) is initially obtained in S31, and the control flow goes to steps S32-S35, which are similar to the steps S1-S4 as described above, except in that flag F12 is set to an ON state in S35 after a movement of the movable guide rail 112 toward the desired position is initiated. Then, S36 is implemented to initiate a movement of the CCD camera 66 toward the desired position. The desired position is obtained in the same manner as described above with respect to the first embodiment. The CCD camera 66 is moved at a higher speed than the movable guide rail 112.

[0058]

Then, the control flow goes to S37 to determine whether the CCD camera 66 has reached the desired position. A negative decision (NO) is initially obtained in S37, and one cycle of execution of the present routine is terminated. Steps S31, S32 and S37 are repeatedly implemented until the CCD camera 66 has reached the desired position. When an affirmative decision (YES) is obtained in S37, the control flow goes to S38 to stop the movement of the CCD camera 66, and turn ON the flag F11.

[0059]

Then, the control flow goes to S39 in which an image of the fiducial mark 222 is obtained by the CCD camera 66 located at the desired position, and image data obtained by the CCD camera 66 are processed. Step S39 is followed by S40 to determine whether the movable guide rail 112 is located at a predetermined position close to the desired position. This determination is effected by determining whether the image of the fiducial mark 222 on the movable guide rail 112 is located within the imaging area of the CCD camera 66. If the image is not located within the imaging area, it means that the movable guide rail 112 has not reached the predetermined position close to the desired position. In this case, a negative decision (NO) is obtained in S40, and one cycle of execution of the present routine is terminated. The determination as to whether the movable guide rail 112 has reached the predetermined position close to the desired position may be made on the basis of the operating time of the width changing motor 210.

[0060]

Steps S31, S39 and S40 are repeatedly implemented until the movable guide rail 112 has been located at the predetermined position

close to the desired position. When the movable guide rail 112 has reached the predetermined position close to the desired position, the image of the fiducial mark 222 can be taken by the CCD camera 66, and an affirmative decision (YES) is obtained in S40, so that S41 is implemented to determine whether a flag F13 is placed in an ON state. The flag F13 placed in the ON state indicates that the movable guide rail 112 has reached the predetermined position close to the desired position, and that the speed of movement of the movable guide rail 112 has been lowered. Since the flag F12 is reset to an OFF state upon initialization or others, a negative decision (NO) is initially obtained in S41, and the control flow goes to S42 to lower the speed of the movement of the movable guide rail 112, and turn ON the flag F13.

[0061]

S43 is then implemented to determine whether the movable guide rail 112 has almost reached the desired position in a similar way to S14 described above. Steps S31, S39, S40, S41 and S43 are repeatedly implemented until the movable guide rail 112 has almost reached the desired position. When an affirmative decision (YES) is obtained in S43, the control flow goes to S44 similar to S15, in which the movable guide rail 112 is stopped at the desired position at which the center of the image of the fiducial mark 222 is aligned with the center of the imaging area of the CCD camera 66. Thus, the operation to locate the CCD camera 66 at the desired position and control the width changing device 214 such that the position of the fiducial mark 222 of the movable guide rail 112 is aligned with the position of the CCD camera 66 is a controlling step. Further, a portion of the control device 250 assigned to implement steps S40 and S42-S44 constitutes a control device operable to control the width changing device

214.

[0062]

While the first embodiment is adapted such that the CCD camera 66 follows the movement of the movable guide rail 112, the movable guide rail 112 may follow the movement of the image-taking device. This modified arrangement will be described as a third embodiment of the invention, by reference to Fig. 11.

[0063]

The width of the PWB conveyor according to the third embodiment is implemented according to a conveyor width changing routine illustrated in Fig. 11. The conveyor width changing routine of Fig. 11 is initiated with steps S61-S63, which are similar to steps S1-S3 of the first embodiment. Namely, the positions of the stationary and movable guide rails 110, 112 are detected. Then, S64 is implemented to initiate a movement of the CCD camera 66 toward the desired position, and turn ON a flag F21. In this embodiment, the speed of movement the CCD camera 66 is controlled in a predetermined pattern.

[0064]

Then, the control flow goes to S65 in which an image of the fiducial mark 222 is taken by the CCD camera 66, and image data obtained by the CCD camera 66 are processed. Step S65 is followed by S66 in which a movement of the movable guide rail 112 is controlled such that the movable guide rail 112 follows the movement of the CCD camera 66. As the CCD camera 66 is moved, the relative position of the image of the fiducial mark 222 and the imaging area of the CCD camera 66 changes. The movement of the movable guide rail 112 is controlled so that the deviation of the center of the image of the fiducial mark 222 with respect to

the center of the imaging area of the CCD camera 66 is zeroed. If the movable rail 112 follows the CCD camera 66 in its movement toward the desired position, the amount of electric current to be applied to the width changing motor 210 is increased by an amount corresponding to the distance between the movable guide rail 112 and the CCD camera 66. If the movable guide rail 112 leads the CCD camera 66, the amount of electric current is reduced by an amount corresponding to the distance. As a result, the movable guide rail 112 is moved at a speed which is controlled in substantially the same pattern as that of the CCD camera 66.

[0065]

Then, S67 is implemented to determine whether a flag F22 is placed in an ON state. The flag F22 placed in the ON state indicates that the CCD camera 66 has reached a predetermined position close to the desired position. Since the flag F22 is reset to an OFF state upon initialization or others, a negative decision (NO) is obtained in S67, and the control flow goes to S68 to determine whether the CCD camera 66 has reached the predetermined position close to the desired position. A negative decision (NO) is initially obtained in S68, and one cycle of execution of the present routine is terminated.

[0066]

Steps S61 and S65-S68 are repeatedly implemented until the CCD camera 66 has reached the predetermined position close to the desired position. When an affirmative decision (YES) is obtained in S68, the control flow goes to S69 to decelerate the CCD camera 66, and turn ON the flag F22.

[0067]

The control flow then goes to S70 to determine whether a

flag F23 is placed in an ON state. Since the flag F23 is reset to an OFF state upon initialization, a negative decision (NO) is initially obtained in S70, and the control flow goes to S71 to determine whether the CCD camera 66 has reached the desired position. If a negative decision (NO) is obtained in S71, one cycle of execution of the present routine is terminated. Steps S61, S65-S67, S70 and S71 are repeatedly implemented until the CCD camera 66 has reached the desired position. As a result of the deceleration of the CCD camera 66, the movable guide rail 112 is also decelerated since the movement of the movable guide rail 112 is controlled so as to follow the movement of the CCD camera 66.

[0068]

When the CCD camera 66 has reached the desired position, an affirmative decision (YES) is obtained in S71, and the control flow goes to S72 to stop the movement of the CCD camera 66, and turn ON the flag F23. Then, S73 is implemented to determine whether the movable guide rail 112 has almost reached the desired position. This determination is effected in substantially the same manner as described above with respect to S14 described above. A negative decision (NO) is initially obtained in S73, and one cycle of execution of the present routine is terminated. When the movable guide rail 112 has almost reached the desired position, an affirmative decision (YES) is obtained in S73, and S74 is implemented and the present routine is terminated. Thus, the operation to control the width changing device 214 so as to zero the deviation of the center of the image of the fiducial mark 222 with respect to the center of the imaging area of the CCD camera 66 is a controlling step. Further, a portion of the control device 250 assigned to implement S66 constitutes a tracing control portion. This tracing control portion cooperates with a portion of the control device

250 assigned to implement steps S73 and S74 to constitute a control device operable to control the width changing device 214.

[0069]

In the illustrated embodiments described above, the two fiducial marks 220, 222 are provided on the respective stationary and movable guide rails 110, 112. However, a plurality of fiducial marks may be provided on each of the two guide rails 110, 112. Further, the preceding embodiments are arranged to move the movable guide rail 112 to change the distance between the stationary and movable guide rails 110, 112, uniformly in its lengthwise direction. However, the conveyor width may be changed at a plurality of positions in the Y-axis direction independently of each other. These arrangements will be described as a fourth embodiment, by reference to Fig. 12.

[0070]

The fourth embodiment includes a width changing device 356 for changing the width of a PWB conveyor 350, that is, for changing a distance between a stationary guide rail 352 and a movable guide rail 354 of the PWB conveyor 350. As schematically shown in Fig. 12, the width changing device 356 includes a plurality of (two in the present embodiment) feedscrews 360, each of which is rotatably supported at its longitudinally opposite ends by the stationary guide rail 352 and a support member 362. The feedscrews 360 are held in meshing engagement with respective nuts 364 fixed to the movable guide rails 354. The two feedscrews 360 are connected through respective speed reducing devices 368 to respective width changing motors 366 mounted on the stationary guide rail 352. The movable guide rails 354 is moved toward and away from the stationary guide rail 352 when the two feedscrews 360 are rotated by the respective

width changing motors 366 independently of each other. In the present embodiment, the movable guide rail 354 is moved at two positions spaced in the longitudinal direction independently of each other. The movable guide rail 354 is guided by a guiding device (not shown) including guide rails, guide rods or others. In Fig. 12, some elements including a mechanism for feeding the printed-wiring board 24 are not shown.

[0071]

Each of the stationary and movable guide rails 352, 354 is provided at its longitudinally opposite end portions with respective fiducial marks 370 or 372, which are located at the positions corresponding to the respective two feedscrews 360. Thus, the PWB conveyor 350 uses two pairs of fiducial marks 370, 372.

[0072]

The width of the PWB conveyor 350 is changed in the same manner as in the first embodiment of Figs. 1-9. Namely, the CCD camera 66 is moved so as to follow the movement of the fiducial mark 372. Since there are provided two pairs of fiducial marks 370, 372, the CCD camera 66 is moved to follow the movement of one of the two fiducial marks 372. However, the positions of the stationary and movable guide rails 352, 354 are detected on the basis of the images of all of the two pairs of fiducial marks 370, 372. In the present embodiment, two desired positions of the movable guide rail 354 are determined on the basis of the positions of the two fiducial marks 370 of the stationary guide rail 352 and the desired distance of the two rails. However, the movement of the CCD camera 66 so as to trace the movement of the movable guide rail 354 is controlled on the basis of one of the two desired positions of the movable guide rail 354.

[0073]

When the width of the PWB conveyor 350 is changed, the two electric motors 366 are operated in synchronization with each other to drive the respective two feedscrews 360, so that the movable guide rail 354 is moved toward or away from the stationary guide rail 352, uniformly in its longitudinal direction. The CCD camera 66 follows one of the two fiducial marks 372 of the movable guide rail 354, and when the CCD camera 66 has almost reached the desired position determined on the basis of the position of the fiducial mark 370 paired with the followed fiducial mark 372, the CCD camera 66 is moved so as to reach the desired position, before the movable guide rail 354. At this desired position, the CCD camera 66 takes an image of the above-indicated one fiducial mark 372, and the movable guide rail 354 is moved to and stopped at the desired position. Then, the CCD camera 66 is moved to the desired position corresponding to the other fiducial mark 372, and takes an image of this other fiducial mark 372. If the position of the image of this other fiducial mark 372 deviates from the center of the imaging area of the CCD camera 66, that is, from the desired position in the Y-axis direction, the width changing motor 366 corresponding to the above-indicated other fiducial mark 372 is operated to move the corresponding end portion of the movable guide rail 354, so as to zero the above-indicated deviation. In this manner, the desired width of the PWB conveyor 350 can be accurately established.

[0074]

As described above, the fourth embodiment uses the two pairs of fiducial marks 370, 372, and is arranged to change the distance between the stationary and movable guide rails 352, 354, at two positions of the guide rails (that are spaced apart from each other in the longitudinal direction), independently of each other, so that the desired width of the PWB

conveyor 350 can be established with a higher degree of accuracy over the entire length of the guide rails 352, 354.

[0075]

The distance between the stationary and movable guide rails may be changed at three or more different longitudinal positions of the guide rails independently of each other. The longitudinal positions at which the width is changed independently of each other are determined depending upon the constructions and positional arrangements of the PWB conveyor and the adjacent members, for example. Where the width is changed at three longitudinal positions of the guide rails, for instance, the width is preferably changed at the longitudinally opposite end portions and intermediate portion of the guide rails, for example. In this case, three feedscrews are preferably provided at the respective three longitudinal positions of the guide rails, and at least three pairs of fiducial marks are preferably provided, including three pairs provided at the respective three longitudinal positions corresponding to the three feedscrews.

[0076]

Further, the number of the longitudinal positions of the stationary and movable guide rails at which the width of the PWB conveyor is changed may be different from the number of pairs of the fiducial marks provided on the guide rails. In the embodiment of Figs. 1-9 wherein the movable guide rail is moved by the single drive source uniformly in its longitudinal direction, two or more pairs of fiducial marks may be provided. According to this modification, the two or more pairs of fiducial marks are spaced apart from each other in the longitudinal direction of the guide rails, for instance. In this case, an average of the positions of the two or more fiducial marks of the stationary guide rail is used as the position of the

stationary guide rail, and the desired position of the movable guide rail is determined on the basis of the average position of the stationary guide rail and the desired width of the desired distance between the stationary and movable guide rails. Initially, the movable guide rail is moved to the desired position on the basis of an image of one of the fiducial marks of the movable guide rail. Then, images of the other fiducial marks of the movable guide rail are taken one after another, to adjust the Y-axis position of the movable guide rail on the basis of the images of those fiducial marks, if the actual positions of the movable guide rail corresponding to those fiducial marks deviate from the desired position by more than a predetermined amount.

[0077]

In the illustrated embodiments described above, the movable guide rail 112, 354 is decelerated when the CCD camera 66 has reached a position close to the desired position, so that the movable guide rail is moved at a relatively low speed until the movable guide rail has almost reached the desired position. However, the speed of movement of the movable guide rail may be gradually lowered to stop the movable guide rail at the desired position, by gradually reducing the time of energization of the width changing motor. The time of energization of the width changing motor may be reduced linearly or in steps, or along a predetermined curve. The width changing motor may be provided with a brake, to stop the movable guide rail at the desired position in a shorter time and with higher accuracy.

[0078]

While the illustrated embodiments are arranged such that the movable guide rail 112, 354 is decelerated when it has reached a predetermined position close to the desired position, a continuous movement

of the movable guide rail 112, 354 may be changed to an intermittent movement, instead. The distance of each of the intermittent motions may be kept constant, or decreased as the movable guide rail approaches the desired position.

[0079]

Where the CCD camera is moved so as to follow the movable guide rail, the CCD camera may be moved to the desired position when the movable guide rail has reached a position close to the desired position. This is possible since the position of the movable guide rail can be obtained on the basis of the position of the CCD camera and the position of the image of the fiducial mark 222.

[0080]

In the first embodiment wherein the CCD camera is moved so as to follow the movable guide rail, the movement of the CCD camera so as to follow the movable guide rail is terminated when the CCD camera has reached a position close to the desired position, and the CCD camera is further moved to the desired position before the movable guide rail reaches the desired position. However, this arrangement is not essential. In this respect, it is noted that even if the CCD camera keeps following the movable guide rail, the position of the movable guide relative to the desired position can be obtained on the basis of the position of the CCD camera, so that the movable guide rail can be stopped at the desired position.

[0081]

Where the movable guide rail is moved by the operator by performing an inching operation of the width changing motor, and position data indicative of the movable guide rail are not stored in the RAM, the position of the movable guide rail may be detected by moving the CCD

camera over a predetermined search range determined by the range of the operating stroke of the movable guide rail, to search the fiducial mark provided on the movable guide rail, as in the case where the movable guide rail is moved by the operator using the handle 218.

[0082]

Although each image-taking device used in the illustrated embodiments is arranged to take a two-dimensional image of the object, the image-taking device may be a line sensor having a straight array of multiple imaging elements, which is moved relative to the object to take multiple line images one after another, so as to obtain a two-dimensional image of the object. Where the line sensor is used, the line sensor is moved by a suitable feeding device, to take an image of a fiducial mark, which is used to control the width changing device.

[0083]

In the illustrated embodiments, the images of the fiducial marks 220, 222 provided on the guide rails 110, 112 are taken by the CCD camera 66 which is provided to take the images of the fiducial marks 65 provided on the printed-wiring board 24. However, the images of the fiducial marks 220, 222 may be taken by other image-taking devices if provided for some other purposes.

[0084]

The method according to the present invention is applicable to a variable-width substrate conveyor which includes a substrate loading portion, a substrate positioning portion and a substrate unloading portion and in which a circuit substrate received from the substrate loading portion is positioned and supported by the substrate positioning portion, so that an electric-component mounting device or other substrate handling device is

moved by a moving device in a plane parallel to the surface of the circuit substrate, for performing a desired working operations at predetermined positions on the circuit substrate. The substrate positioning device may be arranged to move the circuit substrate in only the feeding direction of the substrate conveyor, or in both of the feeding direction and a direction which is parallel to the circuit substrate and perpendicular to the feeding direction. In this variable-width substrate conveyor, each of the substrate loading, positioning and unloading portions has a pair of parallel guide rails. The three portions may be provided with respective width changing devices for changing their widths independently of each other. Alternatively, the three portions may be connected to each other, and use a single common width changing device for changing the width of the connected three portions at one time. Each width changing device may use a single drive source, or a plurality of drive sources which are operable independently of each other to change the distance between the two guide rails at different longitudinal positions of the guide rails.

[0085]

The fiducial mark or marks provided on the movable guide rail may be taken by the image-taking device after the movable guide rail is located at the desired position, so that the image or images of the fiducial mark or marks is/are used to check if the movable guide rail is accurately located at the desired position, and to correct the actual position of the movable guide rail, if necessary.

[0086]

The method of the present invention is equally applicable to a substrate conveyor used to transfer a circuit substrate in various devices other than the electric-component mounting device, such as a screen printer,

an adhesive dispenser and other high-viscosity fluid coating devices, a re-flow furnace for melting a solder paste, and a circuit inspecting device.

[0087]

While the presently preferred embodiments of this invention have been described in detail, for illustrative purpose only, it is to be understood that the present invention may be embodied with various other changes and improvements, such as those described in the part "Objects to be Attained by the Invention, Means for Attaining the Objects", which may occur to those skilled in the art.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a plan view schematically showing an electric-component mounting system including a printed-wiring-board conveyor which is constructed according to one embodiment of the present invention and the width of which is changed by a method according to the invention.

[Fig. 2]

Fig. 2 is a side elevational view (partly in cross section) of an electric-component mounting device of the electric-component mounting system of Fig. 1.

[Fig. 3]

Fig. 3 is a front elevational view (partly in cross section) of the electric-component mounting device of Fig. 2.

[Fig. 4]

Fig. 4 is a plan view of the printed-wiring-board conveyor.

[Fig. 5]

Fig. 5 is a side elevational view of the printed-wiring-board conveyor.

[Fig. 6]

Fig. 6 is a view showing a stationary guide rail of the printed-wiring-board conveyor, as seen from the movable guide rail toward the stationary guide rail.

[Fig. 7]

Fig. 7 is a block diagram schematically showing a control device of the electric-component mounting system for controlling its operation.

[Fig. 8]

Fig. 8 is a block diagram schematically showing an arrangement of a RAM of a computer which constitutes a major portion of the control device of Fig. 7.

[Fig. 9]

Fig. 9 is a flow chart illustrating a conveyor-width changing routine stored in a RAM of the computer.

[Fig. 10]

Fig. 10 is a flow chart illustrating a conveyor-width changing routine executed according to a program stored in a RAM of a computer of a control device of an electric-component mounting system including a printed-wiring-board conveyor constructed according to a second embodiment of this invention.

[Fig. 11]

Fig. 11 is a flow chart illustrating a conveyor-width changing routine executed according to a program stored in a RAM of a computer of a control device of an electric-component mounting system including a

printed-wiring-board conveyor constructed according to a third embodiment of the invention.

[Fig. 12]

Fig. 12 is a plan view schematically showing a printed-wiring-board conveyor constructed according to a fourth embodiment of this invention.

[Description of Reference Numerals]

12: electric-component mounting system 24: printed-wiring board

56: XY robot 66: CCD camera 100: printed-wiring-board conveyor

110: stationary guide 112: movable guide 124: endless belt

142: printed-wiring-board feed drive motor 164: feed device

170: guide member 210: width changing motor 214: width changing device 220, 222: fiducial mark 250: control device

350: printed-wiring-board conveyor (PWB conveyor)

352: stationary guide rail 354: movable guide rail

356: width changing device 366: width changing motor

370, 372: fiducial mark